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ON THE TECHNICAL CLASSIFICATION OF METALS

/Following is a translation of an article written by V. A. Pazukhin in Izvestiya Vysshikh Uchebnykh Zavedeniy -- Tsvetnaya Metallurgiya (News of Higher Educational Institutions -- Nonferrous Metallurgy), No. 1, 1960, pages 57-63./

Of all the elements encountered in nature, about seventy which display the set of characteristics embraced in the conception of metal and metals generally find application in our life. The imperative necessity for their classification has therefore arisen.

It must be acknowledged that D. I. Mendeleyev's table of elements is the only scientifically substantiated classification of metals. While irreproachable from this aspect, it is not suitable for everyday economic, industrial and technical usage. Life itself has long since dictated the need for such divisions as ferrous and nonferrous, or chromatic metals, as we colorfully began to name them after the Revolution. Such a division was still satisfactory a half century ago when only the basic nonferrous metals -- copper, lead, zinc -- were smelted in any large quantities and aluminum, nickel, tin and some others were smelted in modest amounts by present standards. But even then the names -- noble metals, junior metals, and others -- were in use. In our time such terms combining various metals -- arising spontaneously -- have become greater in number, because among the nonferrous metals the number is ever-increasing of those metals which have an industrial importance growing almost with every passing year.

In 1948 the Technical Terminology Committee of the Academy of Sciences USSR published the bulletin "Technical Classification of Metals," the result of prolonged work by many of our prominent physical metallurgy specialists. In the bulletin, however, the problem of the classification of metals in themselves and not of their alloys was not solved, since only the division of alloys was developed and only the conception of the purity of metals defined. This was undoubtedly necessary, and therefore its merit is appreci-

ated by everyone who deals with metals. But a technical classification of the metals themselves is also no less necessary for us.

Here is what is said in the bulletin in this connection: "Depending on the name of the basic component (base), all metals are divided into two kinds: black (ferrous) metals and chromatic (nonferrous) metals." The nonferrous metals are those in which the "basic component is any metallic element with the exception of iron (p. 15)." This division has been adopted as one that was formed historically by virtue of the exceptional importance iron has for our entire existence. Throughout the world, in fact, about 14 times more iron is smelted than all other metals taken together, and in annual output iron is of slightly less value than all other metals.

In the classification of nonferrous metals, it is said: "The chromatic (nonferrous) metals are divided into separate kinds of metal depending on the basic component. The separate kinds of chromatic (nonferrous) metals are arranged in the ascending order of the atomic number of the chemical elements that are the basic components." In other words, a classification of the nonferrous metals is wholly lacking in the bulletin, while their listing in the order indicated is proposed and even the division of them by groups of the periodic system is thus not recommended. The incompetence of such a capitulation before the difficulties of technical classification is clearly evident from the following lines: "The absence of intermediate groupings (between genus and species) of chromatic (nonferrous) metals causes a series of inconveniences. The existing groupings of chromatic (nonferrous) metals should be admitted unfortunate in view of the variability, indefiniteness and chance character of the classifying criteria. Referred to here are the terms: "precious metals," "noble metals," "dispersed metals," "rare metals" and "junior metals." In the bulletin, these names are scrapped because it is essential to observe unity of the classifying criterion and to solve the problem as a whole for all kinds, and not by means of the gradual exclusion of separate kinds of metals. This matter is considered hopeless inasmuch as apart from the atomic number there is no single criterion for the technical classification of nonferrous metals.

But this not at all so. In its time, actual life and not merely some committee required that iron be distinguished from all other metals. The same kind of imperative need later gave rise to the other names of the various groups of metals indicated above. We use all these names and easily understand what they mean fundamentally. Instead of

rejecting the technical classification of metals, it is therefore necessary, insofar as possible, to make precise, comprehend, and supplement the division of metals into groups that has already arisen.

If we turn to other sciences, to zoology, for example, we see that the orders which combine, let us say, the family of mammals, are distinguished not by a single characteristic of structure, but by many applied in sequence. Is it not right for us to do the same for the orders and groups of metals as well, notwithstanding what is said in the bulletin about the possibility of classification by one characteristic only? Then every order will include varieties -- isotopes; the species -- a set of a given metal's isotopes; the genus -- sorts of its varied purity; and the family -- commercial grades of metal or the natural alloys with its marked predominance as the base.

Essentially, not one characteristic, but two -- practice and industrial importance -- are also employed in the bulletin in the isolation of ferrous metals, i. e. iron and its alloys into a special group. Why cannot we also proceed further in this way, grounding the division of metals into groups not by one but by several characteristics which are employed in a series, after having put at the basis the two characteristics indicated above, inasmuch as these very criteria are confirmed by life.

The classification of nonferrous metals which has been adopted by life and has found reflection in the names of books, journals, chairs, specialties among metallurgists, research institutes, industrial combines and factories gives grounds in the first place to distinguish the following groups of metals: heavy nonferrous metals, light metals, noble metals, rare metals.

Following the second criterion, the industrial importance of metals, this division can be well grounded, supplementing it with several more groupings.

Proceeding from these premises, the author in 1946 already proposed a technical classification of metals. While this work was not published, it became known to many metallurgists. The profound changes in metallurgy during recent years have required a revision of this classification which in corrected form is offered to the reader's attention with necessary explanations.

Under heavy nonferrous metals we all understand first of all copper, lead, and zinc. Throughout the world annually approximately two million tons each of these are smelted, i.e. more than other nonferrous metals taken together (without aluminum). Their smelting is also sharply predominant in our country. This group fully meets the next, third

criterion of classification, the geochemical, or predominant form of occurrence in nature. These metals are smelted, in fact, chiefly from sulfide ores in which they are usually encountered combined in various compounds and ratios. According to this same characteristic, nickel must be included in the same group as one of the most important industrial metals, although it is smelted less. Finally, the unfailing accessories of these metals in mines and metallurgical reductions, cobalt and cadmium, should also be included in the group of heavy nonferrous metals. The specific weights of all these metals are, by the way, more than seven, a fact which also justifies their common name.

In the third group of light metals, i.e. with low specific weight, we class first of all aluminum, the world smelting of which is now approximately one-and-a-half times greater than that of copper, lead or zinc, without even mentioning other nonferrous metals. Magnesium and alkali metals are included in this group because, like aluminum as well, they are smelted by electrolysis from saline melts.

Resemblance of metallurgical reductions, the fourth criterion of the classification (applicable also to the group of heavy metals), is here quite distinctly manifested. By this characteristic, calcium and beryllium should also be included in the group but they are produced also by metallothermic means while calcium is at the same time volatilized in a vacuum. Produced by the latter method are all barium and strontium, and sometimes magnesium and the rarer alkali metals. Apart from resemblance in basic metallurgical reductions, the light metals are situated side by side in the periodic system and are related in geochemical characteristics.

The fourth group is junior metals. In it we classify, according to the primary criterion, industrial importance, the metals which are smelted in substantially less quantities than are the basic nonferrous metals, but have an important though also subordinate significance in life. All of these metals are of low-melting-temperature, while their oxides are readily reducible -- a fact which makes the methods of smelting them from ores similar. They are related geochemically, since even tin from the sulfide polymetallic ores acquires ever-increasing importance in our country. Cadmium and cobalt are often included in this group. I think that this should not be done. Cadmium in nature is encountered only dispersed and, as was indicated, is derived as a secondary product of the reduction of polymetallic ores. Cobalt, it is true, forms agglomerates in nature and is often connected in the ores with silver and bismuth, but the means of reduction of even such ores differs

Technical Classification of Metals

Groups of metals by technical classification	Name of Metal	Groups by periodic system
1. Ferrous	Iron (steel, pig iron)	VIII
2. Heavy non-ferrous	Copper	I
	Nickel, cobalt	VIII
	Zinc, cadmium	II
	Lead	IV
3. Light	Aluminum	III
	Magnesium	II
	Calcium, strontium, barium	II
	Beryllium	II
	Sodium, potassium	I
	Lithium, cesium, rubidium	I
4. Junior	Tin	IV
	Antimony, bismuth	V
	Mercury	II
5. Noble	Silver, gold	I
	Platinum, palladium	VIII
	Iridium, rhodium	VIII
	Osmium, ruthenium	VIII
6. Refractory	Tungsten, molybdenum	VI
	Tantalum, niobium	V
	Titanium, zirconium, hafnium	IV
	Rhenium	VII
7. Ferro-alloy (ferrous)	Manganese	VII
	Chromium	VI
	Vanadium	V
8. Rare metals	Lanthanum, cerium and other lanthanides	II
	Scandium, yttrium	II
9. Semi-metal (semiconductor)	Silicon, germanium	IV
	Arsenic (stibium)	V
	Selenium, tellurium	VI
10. Dispersed	Gallium, indium, thallium	III
11. Splitting	Radium	II
	Actinium, thorium, uranium and other actinides	III
	Radioactive isotopes of other metals	

sharply from that applied for the extraction of other metals of this group.. But, for Soviet industry, cobalt has paramount importance as an accessory in the ores of copper and, especially, of nickel.

The fifth group is noble metals. Gold and silver, the principal metals of this group, have from time immemorial been distinguished among the other metals available to people by their brilliance, permanence and exchange value. With the discovery of platinum and acquaintance with its properties, it was naturally included in this group. After that, the other platinum metals were also classed here.

The objection is sometimes raised among us against naming these metals noble, on the grounds that these ideas were formed from feudal relations and the social inequality of people from birth, and thus are alien to our way of life. Now, however, this conception no longer denotes among us a privileged social position, without personal services, but a combination of qualities that inspire respect and even admiration, as for instance, "a noble deed."

Applied to these metals, the name "noble" underscores their brilliance and permanence in nature and everyday life. Gases of the zero group, which do not enter into reaction in general, are also called noble. The name "precious" for these metals is no longer correct because the cost of very many metals greatly exceeds the price of gold.

This group also meets the geochemical and metallurgical criteria of the classification. In fact, gold and platinum in nature are native and dispersed. Silver is an unfailing accessory of gold; although in dispersion the greater part is found in the form of sulfide, silver is almost always accompanied by gold. Mining by washing and their extraction as accessory minerals during the smelting of ores of heavy nonferrous metals allies them in a metallurgical sense.

Classed in the sixth group are the refractory metals. If the metals are classed according to fusibility, then up to palladium, which smelts at 1,554°, the temperature of smelting rises more or less smoothly. Next in this list is the industrial metal zirconian which melts at 1,750°, i.e. almost 200° higher. If the platinums which, by other characteristics, were previously classed in the noble group and if chromium (smelting temperature 1,800°) is excluded from the number of more refractory metals, then eight metals remain in the group.

All of them have acquired great industrial importance, but diminishing in the listed order from the most important tungsten to the hard-of-access rhenium, an unfailing accessory of molybdenum. Refractoriness, their marked

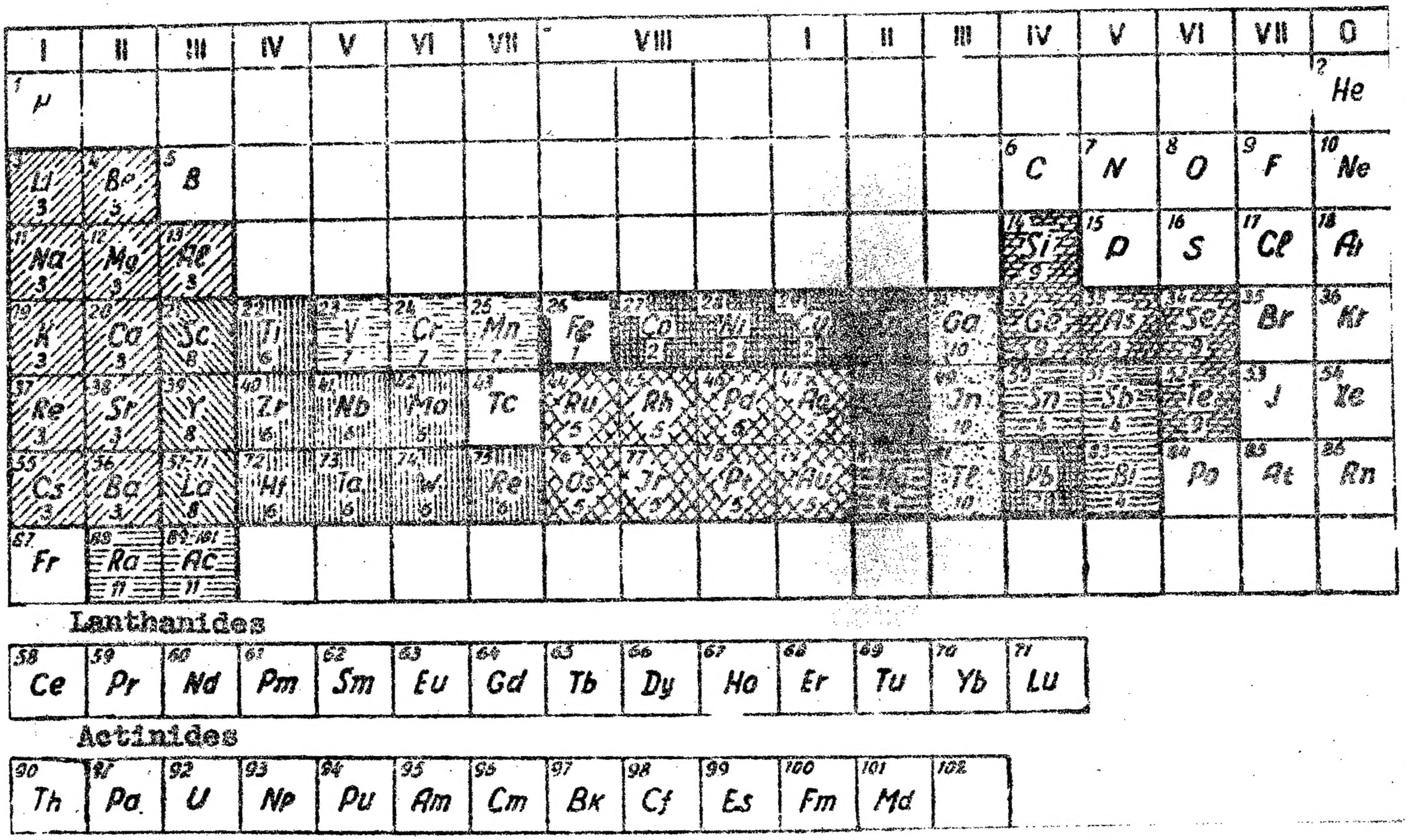
characteristic, is combined with their other properties: hardness, heightened resistance to corrosion, capacity to give very hard, durable carbides. The latter together with the hardness of the metals themselves determines their wide application in alloys, especially the hard and super-hard. By reason of their refractory nature, they are usually produced spongy, then caked and most frequently smelted in a vacuum. They are located as a cluster in the periodic table. In nature they are frequently encountered together and, apart from molybdenum, usually in the form of combinations of their higher oxides with other oxides.

The next, seventh group is the ferro-alloy metals. The concept of the ferro-alloys has already been fully formed, and it is superfluous to explain it here. Manganese and chromium are the most important metals in alloys of this kind. They are smelted in many millions of tons and the smelting of a large proportion of quality steel is based on them. To them has to be added vanadium which in itself is not utilized as yet and is little employed apart from steel in alloy form. But its value is extremely great and only the small prevalence in nature limits its application. Together with pig iron, steel and ferro-alloys, these metals are also called ferrous. In this group might have been classed a large part of the refractory metals, especially tungsten and partially, molybdenum, which is an addition to steel more often in the form of molybdate than ferro-alloy. Nickel is almost always added to steel in the pure form, granulated, and recently in the form of oxide like molybdate. Nickel and other metals are therefore classed as refractory and should not be mixed in the ferro-alloy group.

Classed in the eighth group are the rare metals which only in recent years have we learned to produce in pure form and which are gradually finding increasing application in our life. The resemblance of characteristics and conditions of occurrence in nature justify this grouping.

The semiconductors which acquire ever greater importance are classed in the ninth group. For them should be retained the ancient name of "semi-metals" which is met as early as M. V. Lomonosov. All semi-metals are located nearby in the periodic system.

The dispersed metals (gallium, indium, thallium) form the tenth group. In it might have been included rhenium and germanium, rubidium and cesium, selenium and tellurium which have found a better place in other groups. All these metals are called also rare. Our classification does not have such a group on the following grounds: among rare metals were quite recently still classed all nonferrous



Periodic system of D. I. Mendeleyev.

The figures under the symbols of metals denote groups in the technical classification.

metals, apart from the heavy, the noble, certain light and other metals, in all about fifty. The unsatisfactory nature of such a grouping induced, for example, Zelikman, Samsonov and Kreyn in their book "Metallurgiya redkikh metallov" (Metallurgy of Rare Metals), Moscow, 1954, to divide these metals into five groups, roughly according to the same criteria as in my previous classification -- certain metals to which the last chapters of their book are assigned not finding a place in the groups. And there are no grounds to combine all these groups under a common name because the idea of "rare" as applied to metals is extremely indefinite and variable. The recently rare uranium, for example, has ceased to be such for the last 10 to 15 years.

The last, eleventh group combines the radioactive or splitting metals. They are encountered in nature in exceedingly dispersed form or also in the composition of extremely lean ores (uranium) and monazite scatterings (thorium). The separation of them into a special group is justified by the very striking characteristic reflected in the group name. This fifth criterion, radioactivity, can be applied to the fissile isotopes of all other metals. The classing of these isotopes in the group is justified by the special methods of working with them and the derivation of them from ordinary metals at the expense of atomic energy from the splitting of the basic metals of this group.

The table of D. I. Mendeleyev (see the figure) where the listed groups are indicated by varied shadings, clearly shows that the proposed technical classification corresponds in the main to the groupings of metals not only according to the criteria enumerated above, but also according to their mutual proximity in the periodic system, i.e. by the correspondence of their atomic numbers or the structure of their atoms. Hence, some resemblance of the principles of the proposed classification with the Linnaeus classification of animals can be seen.

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From the Editors

In publishing the article "On the Technical Classification of Metals" by Prof. V. A. Pazukhin, the Editors think the idea about the matured need to create such a classification is correct. Admitting that this problem is extremely complex, the Editors ask that readers comment in substance on V. A. Pazukhin's proposal.

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